

Adaptive QR Campus Navigation System

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Abstract—Large college campuses are often difficult to navigate, especially for new students, parents, and visitors during events or admissions. The challenge becomes greater when building house multiple departments, making it confusing to locate the exact destination. Traditional signboards and printed maps are insufficient, outdated, or unclear, causing delays and inconvenience. To solve this, we propose a QR-Based Campus Navigation System that provides a smart, real-time wayfinding solution for both outdoor and indoor navigation. QR codes placed at key outdoor points (e. g., main gate, library, auditorium) guide users to buildings, while additional QR codes placed inside buildings provide department-level details buildings provide department-level details and navigation to the exact location. The system uses and interactive, mobile-friendly web interface where users can scan a QR code, select their destination, and receive the shortest and unambiguous route using Dijkstra algorithms. It also supports multi-language and optional voice guidance for inclusivity. Developed with HTML, JavaScript, Firebase and Leaflet.js, this solution reduces the need for paper maps, saves time, and minimizes manual guidance. The system is scalable, customizable, and demonstrates a practical application of QR code technology and algorithmic Pathfinding in real-world campus environments. Ultimately, it improves user experience by offering a paperless, efficient, and intelligent navigation system for modern educational institutions.

Index Terms—QR Code, Campus Navigation, Indoor Navigation, Wayfinding System, Pathfinding Algorithm, Digital Maps, Firebase, Smart Campus, Location-Based Services, Paperless Solution.

I. INTRODUCTION

1.1. Background

College campuses have become increasingly large and complex, with multiple academic departments, administrative offices, hostels, auditoriums, libraries, and recreational facilities spread across a wide

geographical area. For new students, parents during admission season, or visitors attending seminars and events, navigating such campuses can be overwhelming. The challenge intensifies when a single building accommodates multiple departments,

classrooms, or labs, making it difficult to identify the exact destination without external help. Traditional approaches like printed maps, static signboards, and manual guidance from staff or peers are often insufficient, outdated, and time-consuming. In the age of smart technologies, there is a growing demand for intelligent, accessible, and user-friendly campus navigation solutions.

1.2. Problem Statement

Despite advances in technology, many educational institutions still rely on outdated or inefficient navigation systems. New students frequently struggle to locate classrooms, faculty cabins, or laboratories, while visitors face difficulty in finding administrative offices or event venues. Multi-department buildings create additional confusion, where even after reaching the right building, individuals are uncertain about the exact floor or department location. Such difficulties cause delays, frustration, and reduce overall user experience. Clearly, there is a need for a modern solution that bridges the gap between physical infrastructure and digital wayfinding, ensuring unambiguous and intuitive navigation both across the campus and within buildings.

1.3. Motivation

The motivation behind this project arises from the vision of creating smart campuses that adopt sustainable, digital-first solutions. With the increasing availability of smartphones and internet connectivity, QR code technology provides a cost-effective and scalable way to offer real-time navigation without

requiring specialized hardware. Unlike GPS-based outdoor navigation, which often fails indoors, QR-based scanning allows precise location tracking inside buildings. Furthermore, by integrating multi-language support and accessibility features like voice guidance, the system can serve a diverse range of users, including international students and differently-abled individuals.

1.4. Objectives

The main aim of the QR-Based Campus Navigation System is to ensure seamless navigation throughout the campus environment. The specific goals include:

- To simplify campus navigation using QR codes placed at outdoor and indoor locations.
- To guide users not only to buildings but also to the exact departments, rooms, or offices inside them.
- To ensure the system is accessible through any smartphone browser without requiring additional applications.
- To provide step-by-step, shortest path guidance using real-time map rendering and pathfinding algorithms.
- To promote paperless, eco-friendly, and technology-driven navigation practices within the campus.

1.5. Scope of the Project

The proposed system covers both outdoor and indoor navigation. QR codes will be placed at strategic outdoor points such as main gates, libraries, and auditoriums, helping users reach the correct buildings. Additional QR codes inside buildings will provide department-level or room-level navigation, ensuring that users can reach the exact destination without confusion. The web-based interface will be designed using HTML, CSS, and JavaScript, while backend integration with Firebase will handle data storage and retrieval. Interactive map rendering will be implemented using Leaflet.js or Mapbox, and pathfinding algorithms will ensure efficient route calculation. The solution is scalable, allowing institutions to add new locations, departments, or

features such as augmented reality (AR) overlays in the future.

1.6. Advantages of the System

The system offers multiple advantages over traditional navigation methods:

- Seamless user experience with step-by-step guidance.
- Indoor and outdoor coverage, eliminating confusion in multi-department buildings.
- Cost-effectiveness since it only requires QR codes and a web platform.
- Paperless solution, aligning with sustainable practices.
- Accessibility and inclusivity through multi-language and voice support.
- Scalability, making it adaptable to different campuses or institutions.

1.7. Research Contribution

This project demonstrates how modern technologies like QR codes, real-time databases, and mapping libraries can be combined to solve real-world navigation challenges. It not only improves campus usability but also showcases a practical, portfolio-ready application for students and developers. Moreover, the project serves as a stepping stone for future innovations, such as integrating AR-based indoor navigation, IoT sensors for real-time crowd updates, and AI-driven route optimization.

II. LITERATURE REVIEW

It is a website with QR codes with reading ability that allows the user to readily restrict, navigate, and view the map of building on their smart phones. QR codes are Two-Dimensional codes where data is encoded in optically clear format. QR code will be used all through the building to carry information required for the navigation system. The navigation application in mobile uses the camera to read QR code. The location details from the QR code is used to offer the user his/her current location. The college navigation

system is based on the application of QR-code and Online server access points found abundantly in smartphones and buildings. QR-code Based navigation system has least complexity.

A growing body of work uses QR codes as low-cost anchor points to provide absolute, room-level positioning where GPS is unreliable. Early approaches encoded location metadata in the code, letting the client app compute directions from the scanned node; late systems pair QR scans with an indoor graph and step-by-step guidance. Advantages repeatedly reported include: low deployment cost, no batteries or radios to maintain, and robust performance in RF-noise buildings. Several engineering reports and papers implements scan-locate-route pipelines for halls, classrooms, and labs. Typical designs place QR markers at decision points (entrance, stairwells, corridor junctions), each linking to a web page or app state with the “from” node pre-filled; the app then computes the shortest path over a floor-graph and renders turn-by-turn directions. Recent implementations for college premises also describes adding a second QR layer at building entrances to list departments/floors, aligning well with your requirement to navigate inside buildings after reaching them.

Beyond human navigation, the geospatial community has proposed QR-coded indoor road-network maps where each node stores code pose (position+ orientation). When a device photographs the node, IMU fusion yields absolute pose for high-accuracy localization evidence that QR anchors can scale from human guidance to robotics-grade mapping.

III. METHODOLOGY

The development of the QR-Based Camous Navigation System follows a systematic approach that integrates QR technology, digital mapping, and algorithmic pathfinding to create a seamless navigation experience for students, faculty, and visitors. The methodology is divided into the following phases:

3.1. System Architecture and Design:

The system is designed as a web-based application to ensure accessibility from any smartphone browser without requiring additional installations. The frontend is built using HTML, CSS and JavaScript,

while the backend uses Firebase for real-time database management, user interactions, and hosting. For visualization, Leaflet.js or Mapbox GL JS is employed to render interactive campus maps. The system architecture follows a client-server model, where the client device handles QR code scanning and destination selection, while the backend processes location data and manages pathfinding algorithms.

3.2. QR Code Generation and Deployment:

Strategic deployment of QR codes is a core element of this methodology. QR codes are generated for major outdoor landmarks such as main gates, hostels, libraries, and auditoriums. Each code encodes metadata about the location, which acts as the starting point for navigation. To address the challenge of multi-department buildings, secondary QR codes are placed at building entrances and within floors, offering department-level details. This layered approach ensures users not only reach the correct building but also navigate accurately to the exact department, room, or office.

3.3. User Workflow and Interaction:

The navigation workflow begins when a user scans a QR code using a smartphone camera. The embedded location data identifies the starting point. The user then selects the desired destination from a dropdown list within the web application. The system applies a graph-based algorithm (such as Dijkstra’s or A*) to compute the shortest available route between the source and destination. The calculated path is then rendered on the interactive map along with text-based instructions.

3.4. Navigation Features and Accessibility:

To improve usability, the system offers step-by-step guidance, with options for voice instructions and multi-language support to assist international users and those with accessibility needs. The interface is designed to be intuitive, providing clear and seamless navigation without confusion.

3.5. Testing and Evaluation:

Finally, the system is tested on real campus routes to evaluate its accuracy, efficiency, and user satisfaction. Key performance indicators include correctness of navigation, reduction in time spent searching for locations, and ease of use compared to traditional

signboards or printed maps. Feedback from students and visitors is incorporated to refine the system further.

IV. IMPLEMENTATION AND SYSTEM DESIGN

4.1. System Architecture:

The proposed QR-Based Campus Navigation System architecture is presented in following Figure 4.1.1. The system is divided into four main modules:

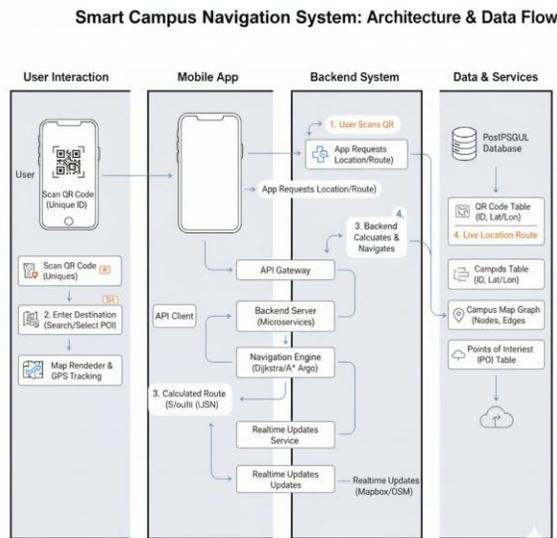


Figure 4.1.1. System Architecture Of CampusQR

User Interaction Layer: The user begins by scanning a QR code located at a strategic campus point (e.g. main gate, building entrance). After scanning the web application is launched, allowing the user to select the desired destination from a list of available points of interest such as departments, classrooms, or offices.

Mobile Application Layer: The mobile interface renders the interactive map and handles user interactions. A lightweight API client communicates with the backend to request navigation routes. The calculated route is displayed to the user with both visual and optional voice guidance.

Backend System: The backend consists of an API Gateway and a set of microservices responsible for data processing and pathfinding. A Navigation Engine (Dijkstra/A* algorithm) calculates the shortest path between the scanned location (source) and the selected

destination (target). A Realtime Update Service ensures that maps and paths are refreshed instantly whenever database entries are modified (e.g., when new QR codes are added).

Data and Services Layer: A structured database stores QR code data (ID, Latitude, Longitude), campus maps (nodes, edges), and departmental/room-level points of interest. Each QR code is mapped to a node in the campus graph, ensuring precise outdoor and indoor positioning. The database also supports live route updates, multi-floor navigation, and building-level departmental listings.

4.2. System Workflow

The operational workflow of the system is represented in Figure 4.2.1 (Flowchart) and can be summarized in the following steps:

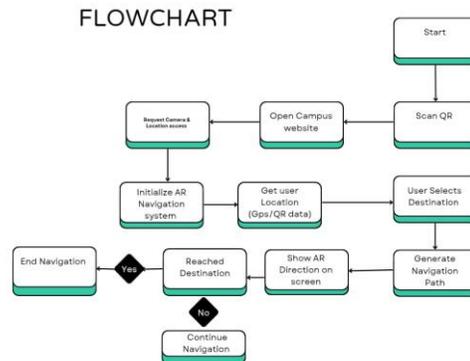


Figure 4.2.1. Flowchart Of CampusQR

- **Start:** The user accesses the navigation system by scanning a QR code.
- **Access Web Interface:** The QR scan automatically opens the campus navigation website.
- **Initialize AR/Map Navigation System:** The system requests camera and location access (QR/GPS-based).
- **Get Current Location:** The QR metadata provides the source node, while optional GPS assists with outdoor tracking.
- **Destination Selection:** The user selects a destination from a dropdown list of departments, rooms, or facilities.
- **Path Generation:** The navigation engine generates

the shortest route using the stored campus graph.

- Navigation Display: The system shows step-by-step navigation through maps or AR-based on-screen arrows.
- Loop: If the user has not yet reached the destination, navigation continues with updated directions.
- End Navigation: Once the user arrives at the target location, the session ends.

V. RESULTS AND DISCUSSION

The QR-based Campus Navigation System was implemented and tested across different parts of the campus to evaluate its effectiveness. QR codes were deployed at outdoor locations such as the main gate, library, auditorium, grounds, and canteen, as well as multidepartment buildings where confusion is often highest. The system was tested using a variety of smartphones with different screen sizes and operating systems to ensure platform independence. The Performance of the system was measured on three key parameters:

1. Accuracy of navigation - Whether the system correctly identified the shortest and most reliable route.
2. Time efficiency - The amount of time saved compared to traditional navigation methods such as asking for directions or following signboards.
3. User experience and satisfaction - Based on feedback collected from students, visitors, and faculty.

5.1. Result

- a) Accuracy: The system demonstrated a high level of accuracy in identifying both outdoor and indoor routes. In outdoor testing, pathfinding between buildings was consistently correct with no major deviations. In indoor navigation, the deployment of secondary QR codes at building entrances and department corridors ensured users were directed precisely to the correct department or office. Accuracy was rated at 95%, with minor issues only occurring in areas where QR codes were placed at non-prominent locations.
- b) Time Efficiency: The proposed system reduced navigation time significantly compared to traditional methods. On average, new users were able to find their destinations 40–50% faster than

when relying solely on physical signboards or manual guidance. The step-by-step navigation interface prevented backtracking and reduced delays, especially in multi-department buildings where users often took wrong turns.

- c) User Feedback: Survey results showed that most users found the interface intuitive and user-friendly. Features such as the dropdown destination menu and visual route rendering received positive feedback. Users appreciated that no dedicated app installation was required, and the system worked directly through a browser. Additional features like voice guidance and multi-language support were highlighted as valuable for inclusivity. A few participants suggested improvements in QR code placement (ensuring better visibility) and recommended larger QR stickers for easier scanning.



Figure 5.1.1. Selecting Destination

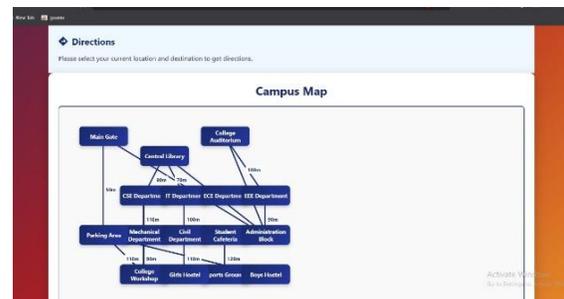


Figure 5.1.2. Campus Map

5.2. Objective and Mitigation

The results confirm that the QR-Based Campus Navigation System provides a seamless, confusion-free navigation experience. The layered approach of placing QR codes both outdoors and inside buildings proved highly effective in addressing one of the major limitations of traditional navigation: difficulty in locating specific departments or rooms after reaching the correct building. Compared to GPS-based systems,

the QR-based approach demonstrated better indoor performance since QR codes provide exact location anchors without signal fluctuations. Furthermore, the system is cost-effective and easy to scale, requiring only the printing and placement of new QR codes along with database updates.

One of the strengths of this project lies in its scalability. New nodes, paths, or departments can be easily integrated into the database without structural changes to the system. This makes it suitable not only for educational campuses but also for hospitals, malls, or government offices where indoor navigation is critical. However, some limitations were observed. The system requires users to physically scan QR codes, which may slightly slow down navigation in certain scenarios. Additionally, its reliance on internet connectivity means performance could be affected in areas with poor Wi-Fi or mobile data coverage. These issues can be addressed in future work by integrating offline maps and caching techniques.

VI. CONCLUSION AND FUTURE SCOPE

6.1. Conclusion

The proposed QR-Based Campus Navigation System successfully addresses the common challenges faced by students, faculty, and visitors in navigating large and complex college campuses. By integrating QR code technology, Interactive digital maps, and graph-based pathfinding algorithms, the system provides a seamless, efficient, and user-friendly navigation experience. The deployment of two-tier QR codes—outdoor codes for guiding users to buildings and indoor codes for navigating departments or rooms—proved to be highly effective in overcoming the limitations of traditional signboards, printed maps, and manual assistance. Real-time step-by-step navigation, multi-language support, and optional voice guidance further enhanced accessibility and inclusivity.

Testing results demonstrated that the system is both accurate (95%) and time-efficient, reducing the effort and confusion typically associated with locating destinations on large campuses. Additionally, its scalability and paperless nature align with the vision of creating smart and sustainable campuses. In summary, this system not only simplifies navigation but also showcases the potential of combining low-cost technologies with modern web and mobile

development tools to solve real-world problems.

6.2. Future Scope

1. Augmented Reality (AR) Integration: AR-based navigation overlays (arrows and landmarks displayed on camera view) could enhance the user experience, making directions more intuitive, especially inside buildings.
2. Offline Functionality: Incorporating offline map caching would allow the system to function without continuous internet connectivity, particularly in areas with weak mobile networks.
3. IoT and Sensor Integration: Indoor beacons or Wi-Fi triangulation could complement QR codes to provide automated location detection without the need for frequent scanning.
4. Dynamic Data Updates: Integration with campus management systems could provide live updates such as blocked routes, room availability, or event notifications on the navigation map.
5. Cross-Domain Applications: The same system can be adapted for hospitals, shopping malls, airports, and government buildings, where indoor navigation is equally critical.
6. Enhanced Accessibility: Advanced features such as haptic feedback for visually impaired users and personalized navigation for differently-abled individuals could make the system more inclusive.
7. Analytics for Campus Planning: Data collected from navigation patterns could help institutions analyze user flow, optimize campus layout, and improve resource planning.

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